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SPRING-AND-SHOCK-ABSORBER SYSTEM HAVING DIFFERENTIAL ROLL BELLOWS

Description

The present invention relates to a combined spring-and-shock-absorber system for supporting wheel suspensions or axles on a vehicle body using a tubular roll bellows (U-bellows) arranged between a wheel-bearing or wheel-controlling connection and a connection on the vehicle body side, the bellows being arranged between an outer bell and a rolling piston, the outer bell and the rolling piston, in each case, over the height of the corresponding component, having at least partially varying diameters with respect to the walls that contact the tubular roll bellows, and both ends of the tubular roll bellows being sealingly secured on the rolling piston at segments having different diameters, the lower mounting section having a larger diameter than the upper mounting section.

From U.S. Patent 4,518,154, a pneumatic suspension system of this type for vehicles is known. The outer bell and the multi-part rolling piston enclose a unitary differential roll bellows. Due to the low gas pressure and the use of a differential roll bellows, this design requires an installation space of an excessively large volume.

In addition, from German Patent 297 02 927 C1, a spring-and-shock-absorber system is known, which is composed of a displacement device without a bellows, a hydraulic accumulator, and a hydraulic line connecting these parts. In the hydraulic line, a mechanical choker valve is arranged. The displacement device, as is familiar in a hydropneumatic suspension system, connects the vehicle wheel suspension to the vehicle body. The system is filled with a hydraulic fluid. The latter, when a vehicle wheel is spring deflected, is forced through the choker valve into a hydraulic accumulator.

The flow resistance of the choker valve generates a damping force, whereas the compression of the gas volume in the hydraulic accumulator creates a spring force. In accordance with the principle of displacement presented here, a displacement piston plunges into a displacement cylinder. Both parts move in a guiding and sealing interaction, generating friction against each other. The friction impairs the response time of the spring-and-shock-absorber system, so that when it is used in a vehicle, the driving comfort of wheels supported by this system is not optimal.

From numerous publications and from practice, diverse motor vehicle air suspension systems are known. They are essentially composed of a roll bellows that encloses a volume of air and that is bordered on its one end by a chassis-fixed covering plate and on its other end by a wheel-side rolling piston. Conventional air spring systems of this type have no stability with regard to tilting, so that additional measures are required for the longitudinal and transverse guiding functions.

The present invention is based on the problem of developing a combined spring-and-shock-absorber system, which contains a low-friction, thin-design displacement device that is based on a tubular roll bellows and that has great transverse rigidity. In addition, the objective of the present invention can be seen in creating a suspension device that is acted upon by a pressure medium, the device being controllable with regard to suspension performance and the height of the spring, and it being such that it is completely or at least substantially possible to do without external longitudinal and transverse suspension links.

The problem is solved by the features of the main claim. For this purpose, a tubular roll bellows is used, which is configured as a differential roll bellows, whose interior is filled with a fluid and communicates to a hydraulic

accumulator that is supported on the chassis or on the vehicle side.

The type of displacement bellows, the type of connection on the chassis and on the vehicle body, and the fact that the bellows interior is filled with a fluid that is prestressed using a gas make possible a slim displacement device that does not have a mechanical, friction-producing longitudinal guide element. A separate longitudinal guide element is superfluous because the pressure in the displacement bellows, as a result of the two bellows meniscuses, centers and stabilizes the shock-absorber leg parts, which move relative to each other.

In response to a pressurizing or depressurizing of the displacement device, a hydraulic fluid flows back and forth between the displacement device and the hydraulic accumulator via a narrowing of the cross-section in the form of a hydraulic line or an opening. The configuration of the line, or the opening, and the characteristics of the restrictors arranged there influence the system dampening in accordance with the size and shape of the opening cross-section. In this context, the individual restrictor can be configured either as a nozzle or an aperture, or at least as a one-way restrictor. When one-way restrictors are used, at least one valve for each flow direction is arranged in the cross-section of the line, or the opening.

The gas cushion of the hydraulic accumulator normally constitutes the suspension system.

As a result of using a tubular roll bellows in the form of a differential roll bellows, the mechanical friction of the entire system is essentially reduced to the interior friction of the bellows or membrane material. As a result, the spring-and-shock-absorber system demonstrates virtually ideal responsiveness over the entire range of damping rates. The outer bell and/or the rolling piston can each be directly

secured--even without the interposition of rubber-elastic elements--on the vehicle body, or on the chassis, via flexible couplings. This reduces, inter alia, the component weight, the manufacturing costs, the difficulty of assembly, and maintenance costs.

Both rolling piston halves, in addition to the two corresponding halves of the differential roll bellows in the suspension device according to the present invention, provide a self-centering guide function between the double rolling piston and the outer bell. On account of the relatively high operating pressure -- in comparison to conventional air suspension systems -- this radial guidance is especially stable.

On the other hand, due to the rubber-elastic decoupling of piston and outer bell, the excitation of higher-frequency vibrations is filtered out. The shape of the suspension device as a differential roll bellows is oblong, which, in addition to the very good radial (lateral) guidance, also provides very good longitudinal guidance. For this reason, it is possible, substantially or even entirely, to dispense with a separate longitudinal and transverse control arm.

The spring force is determined by the difference in the effective radii of curvature of the two roll bellows halves (differential roll bellows halves). The radii of curvature of the roll bellows halves are produced by the differences in the radii (or diameters) of the outer bell and the two piston (halves). If the difference between the individual piston radii is slight, then the difference in the radii of curvature of the roll bellows halves will also be slight. This has the consequence that it is possible to operate at a high operating pressure, as is required in active chassis control systems.

The difference in the effective roll-bellows radii of curvature, instead of using a difference in the piston radii,

can be realized using a radius difference of the effective outer-bell segments.

The roll bellows halves, arranged so as to be opposite each other, are clamped, on one side, to the outer bell and, on the other side, to the piston using clamping rings so as to be fixed in a mechanically reliable fashion and tight in the pneumatic/hydraulic sense.

The filling of the spring and the control system, specifically setting the spring level, but also controlling the rolling motion, can be carried out using a controlled pressure pump, which can be connected to the tubular connectors located on the outer bell. In addition, an accumulator volume can also be connected.

For receiving a shock absorber, the piston is preferably configured so as to be a hollow cylinder. In this manner, it is possible to do without a separately arranged shock absorber. This saves both additional installation space as well as additional assembly work. The shock absorber, surrounded by the spring sleeve, is protected from road impurities.

The spring volume of the roll bellows halves can alternatively be filled with a compressed gas (preferably air) or with a hydraulic fluid.

Further details of the present invention can be found in the subclaims and in the description below of two schematically depicted exemplary embodiments:

Figure 1: spring-and-shock-absorber system having a differential roll bellows and an external hydraulic accumulator;

Figure 2: spring-and-shock-absorber system having an

integrated hydraulic accumulator;

Figure 3: spring-and-shock-absorber system having a compressible gas (preferably air) or hydraulic filling.

Figures 1 and 2 each depict a combined spring-and-shock-absorber system, which includes a displacement device (10), a hydraulic accumulator (70, 44, 62), and a fluid-containing working line (76), arranged between the latter and having an integrated choker valve (77, 48, 64).

The displacement device (10) is composed, inter alia, of a multi-stage outer bell (30), an also multi-stage rolling piston (50), and a multi-part differential roll bellows (11), connecting both elements. In response to a spring deflection and rebound, rolling piston (50), secured, for example, on the chassis, moves up and down, centeringly guided by differential roll bellows (11). In this context, exterior wall (23, 24) of differential roll bellows (11) rolls on outer bell (30) and on rolling piston (50).

Outer bell (30) is a hollow body, which contains here two at least partially cylindrical segments (31, 33), which are connected to each other by a transition piece (32) in the shape of a truncated-cone sleeve. In Figure 1, segments (31, 32) and transition piece (33) are made of one part. Upper segment (31) is closed at its upper end by a plate (34). On plate (34), an adapter (35) is formed for the articulated connection to the vehicle body. The interior diameter of the upper, cylindrical segment (31) is, for example, one third smaller than the interior diameter of lower, cylindrical segment (33).

Segments (31) and (33) can also have an interior contour in the shape of a truncated cone. In a case of this type, upper segment (31) would taper towards the top and lower segment

(33) would taper towards the bottom.

Rolling piston (50) also has an upper (51) and a lower segment (55), both segments (51, 55) having, for example, a cylindrical outer shape (56, 57). The exterior diameter of upper segment (51) is smaller than the exterior diameter of segment (55). The exterior diameter of segment (51) is, for example, roughly 60% of the interior diameter of outer-bell segment (31). The diameter differential in the exemplary embodiment is selected so that, in each case, the gap between segments (31) and (51), opposite each other, is roughly the same width in the zones in which meniscuses (21, 22) of differential roll bellows (11) move.

In Figure 1, lower segment (55) of rolling piston (50) is tapered. The tapering begins below the zone which can be contacted by differential roll bellows (11). The lower end of rolling piston (50) ends in an adapter (69) for the articulated connection to chassis (9).

Differential roll bellows (11), arranged between rolling piston (50) and outer bell (30), is composed, inter alia, of two potentially identical tubular roll-bellows halves (12, 13). Roll bellows halves (12, 13) are oriented in a coaxial manner with respect to each other and are mounted on each other in a gas- and fluid-tight manner via a roughly tubular connecting sleeve (14). Connecting sleeve (14) is a short tube, onto which from both sides a roll-bellows half (12, 13) is slid. Each attached segment of corresponding roll-bellows halves (12, 13) is fixed in a non-skid manner on connecting sleeve (14) using a clamping ring (17, 18), for example, in a force- and form-locking manner. In Figures 1 and 2, the connecting sleeve between clamping rings (17, 18) has a tubular segment (15), which is not covered by roll-bellows halves (12, 13). This tubular segment (15) has an exterior diameter which is only slightly smaller than the interior diameter of lower segment (33) of outer bell (30).

To secure differential roll bellows (11) on rolling piston (50), the lower end of differential roll bellows (11), which is open at the tube ends, is slid on interior wall (26) onto the upper end of lower rolling piston segment (55) and is clamped securely using a clamping ring (59). Segment (55) has there a radius that is reduced by the sum of the wall thicknesses of clamping ring (58) and of bellows (11).

In a second step, rolling piston (50) is inserted into differential roll bellows (11), until the upper roll-bellows end reaches the middle of upper segment (51). During the insertion, the lower area of roll bellows (11) is turned back over clamping ring (59), so that exterior wall (24) of bellows (11) contacts rolling-piston segment (55).

In the center of upper segment (51) is located a recess (53), in which interior wall (25) of the upper end of bellows (11) is fixed using a clamping ring (58). The depth of recess (53) is chosen so that the exterior contour of mounted clamping ring (58) has approximately the same diameter as segment (51) in the zone, which, in the assembled state, exterior wall (24) of bellows (11) contacts. Beneath recess (53), in the exemplary embodiments, segment (51) has a diameter which is greater by roughly double the bellows wall thickness in comparison with the diameter of segment (51) above recess (53).

After the mounting of differential roll bellows (11) on rolling piston (50), both parts are inserted into outer bell (30), until connecting sleeve (14), having roll bellows half (12), contacts transition piece (32). For the final positioning of differential roll bellows (11), rolling piston (50) is pulled back into a central position within outer bell (30). In this context, as a meniscus (21) is formed having an upwards orientation, exterior wall (23) of roll bellows half (12) is turned back over clamping ring (58) and outer wall (56) of segment (51).

Consequently, in response to every operationally-caused relative motion between parts (30) and (50), exterior walls (23, 24) of differential roll bellows (11) roll on outer walls (56, 57) and inner walls (36, 37). Because in the exemplary embodiments, meniscuses (21, 22) of differential roll bellows (11) move in narrow annular spaces having cylindrical walls, the centering forces and the transverse rigidity are virtually constant over the entire stroke of the spring-and-shock-absorber leg.

Therefore, meniscuses (21, 22) in the entire stroke range move between rolling piston (50) and outer bell (30) in, for example, cylindrical zones. In this context, meniscus (21) realizes a piston surface, which is, for example, two-thirds ~~smaller than the active piston surface on segment (55).~~

According to Figure 1, the usable overall stroke of the shock absorber leg corresponds to roughly the interior diameter of outer bell (30) in the area of segment (33).

The lengths of individual roll-bellows halves (12) and (13) correspond, for example, to one-and-a-half to double the bellows diameter in the area of the segment (33).

Interior (5), enclosed by differential roll bellows (11), is filled with an incompressible fluid (1), which, according to Figure 1, is under pressure by a gas cushion enclosed in a hydraulic accumulator (70). Hydraulic accumulator (70) is configured, for example, as a bubble or membrane accumulator. Gas cushion (72), divided by the bladder or membrane, constitutes the suspension unit of the spring-and-shock-absorber system.

Hydraulic accumulator (70), which is depicted in an arrangement next to outer bell (30) only by way of example, is connected to bellows interior (5) via a working line (76). For this purpose, working line (76) runs through outer-bell

segment (33) and connects to connecting sleeve (14). In this way, working line (76) itself positions connecting sleeve (14) in outer-bell segment (33) in a form-locking manner.

In housing (74) of hydraulic accumulator (70), on the transition to working line (76), are located two operating pressure-stage valves, opposite each other, in the form of spring-plate valves (77). Each valve (77) opens in one flow direction. In this context, the choking effect of the individual throttle return valve (77) can be carried out so as to be adjustable, if necessary, using a drive that can be controlled or regulated.

If appropriate, a blockable supply line can be connected to ~~working line (76). Assuming use as an active spring-and-shock-~~ absorber system, or as a level regulator, fluid would be supplied or removed from the displacement device via a supply line of this type.

By supplying and removing a predetermined quantity of fluid, additional forces can be realized in an appropriate manner. The supplying or removal of these additional quantities changes the damping and the spring forces in the entire system.

Fluid (1), used in the spring-and-shock-absorber system, is, for example, a solution of water and alcohol. For this solution, all alcohols are appropriate which can be mixed at room temperature in any ratio with water. For example, a water-ethanol solution or a water-glycol solution is used. A conventional water-glycol solution, which is also used as an anti-freeze coolant in internal combustion engines, has, for example, an ethylene glycol component of 33 to 50%. Using a 50-percent solution, it is possible to operate the spring-and-shock-absorber system down to a temperature of -35° Celsius. In addition, this solution does not corrode the usual elastomer materials. Furthermore, the rubber expansion is in

the order of magnitude of the expansion in pure water.

Figure 2 depicts a spring-and-shock-absorber system having two hydraulic accumulators, which are integrated in a space-saving manner. For this purpose, at least lower segment (55) of rolling piston (50) is configured as a hollow body, or a stepped blind-hole bore (61), having at least two hollow spaces (62) and (65), which are separated from each other. The hollow spaces, for this purpose, are arranged, for example, so as to be coaxial with respect to each other.

Exterior hollow space (65) is an annular space, which is formed by the interior wall of rolling piston (50) and a foliated tubular membrane (66). Tubular membrane (66), for this purpose, is fixed at the upper end by a ring adapter (67) in the area of the base of blind-hole bore (61) and at its lower end by a comparable ring adapter (67) in a base plate screwed into rolling piston (50). Annular space (65) is filled with gas via a valve (68) that is situated in this base plate.

Central hollow space (62) is in a hydraulic connection to bellows interior (5) via bore holes (63) and a double-acting leaf valve (64).

The second hydraulic accumulator is arranged in the area of upper outer-bell segment (31). For this purpose, outer bell (30) is surrounded here by, for example, a tubular housing (41). Between this housing (41) and the exterior contour of outer bell (30) is situated a general annular space, which is divided by a tubular membrane (42) into an inner (43) and outer annular space (44). Inner annular space (43) is filled with gas, see valve (45), whereas exterior annular space (44), comparable to fluid space (75) in Figure 1, communicates with bellows interior (5) via at least one leaf valve (48). Leaf valve(s) (48) in the exemplary embodiments according to Figure 2 are situated in a detachable housing (46). Interior space (47) of housing (46) is connected to bellows interior (5) via

working line (76).

If appropriate, spaces (44) and (62) can also be hydraulically connected to each other directly and only communicate with bellows interior (5) via a double-acting leaf valve.

In contrast to Figure 1, a rubber damping element (49), as an elastic limit stop, is located in deaerated return space (7). In addition, upper segment (51) of rolling piston (50) is furnished with a closed bore hole (52) to reduce the unsuspended mass.

Between the chassis and the vehicle body, the spring leg can also be arranged so as to have an outer bell attached in an articulated manner to the chassis. For this purpose, at least the contours of the rolling piston and the outer bell must be adjusted to the new orientation of the rebound spring direction.

As an alternative to the exemplary embodiments described above, a spring-and-shock-absorber system is conceivable in which fluid (1) used in the system is a magneto-rheological fluid. If on hydraulic working line (76), for example, a short annular segment is surrounded by a current-excited solenoid coil, then the excited solenoid coil in combination with fluid (1) represents a variable restrictor. As the current supplied to the coil increases, the flow velocity decreases as a result of an increase in the apparent or dynamic viscosity in working line (76), as a result of which, inter alia, the damping performance of the entire system can be changed in a controlled manner.

Suspension device (2) depicted in Figure 3 is composed of an outer bell (30), which is configured in a cylindrical manner, and an interior piston (50). Piston (50), arranged so as to be co-axial with respect to outer bell (30), is configured as a double rolling piston. First (upper) partial piston (51) of

double rolling piston (50) has exterior diameter (Da), whereas second (lower) partial piston (55) has exterior diameter (Db). Piston (50) made up of partial pistons (51) and (55), is axially movable within outer bell (30) having interior diameter (D_1).

Inside widths (D_1 - Da) and (D_1 - Db) between partial pistons (51) and (55) and outer bell (30) are filled by two roll-bellows halves (12) and (13), arranged opposite each other. Roll-bellows halves (12, 13) form a differential roll bellows (11) and are made of an elastomer material that is reinforced by a fabric insert. A (first) roll bellows (12) is assigned to one partial piston (51), whereas other (second) roll bellows (13) surrounds other partial piston (55). The ends of roll-bellows halves (12, 13) are clamped, on one side, on piston (50) using clamping rings (58, 59), and, on the other side, on outer bell (30) using an exterior ring (14) next to clamping rings (17, 18) in a pressure-tight manner. The exterior ring has two tubular connectors (76, 82) for connecting to a pump and to an accumulator (not depicted); the suspension device (2) can be controlled by tubular connectors (76, 82).

Piston (50), depicted in the drawing, is configured in a hollow cylindrical manner. Its interior contains a shock absorber (80), whose tube is secured on the upper piston end by a spring ring (90). The sealing tightness between shock absorber (tube) (80) and piston (50) is realized by three 0-rings (92, 94, 96). Shock-absorber rod (81) is mounted on a covering plate (86) located on outer bell (30).

If piston (50), mounted on the wheel side, moves axially in relation to chassis-side outer bell (30), then both roll-bellows halves (12, 13), located between piston (50) and outer bell (30), roll, on one side, on the exterior surface of piston (50) and, on the other side, on the interior surface of outer bell (30). The axial force resulting from the application of pressure to roll-bellows halves (12, 13) using

compressed air or hydraulic fluid, is proportional to the difference between the effective roll-bellows radii of curvature.

List of Reference Numerals

1	fluid, water-glycol solution
2	suspension device
5	bellows interior
7	return space
9	chassis
10	displacement device
11	tubular roll bellows, differential roll bellows, bellows
12,13	roll bellows halves, bellows parts
14	connecting sleeve
15	tubular segment
17,18	clamping rings
21,22	meniscuses
23,24	outer walls
25,26	inner walls
30	outer bell
31	upper segment
32	transitional piece
33	lower segment
34	base
35	adapter
36,37	interior walls
41	housing, tubular
42	membrane, hose-like
43	interior annular space
44	exterior annular space
45	valve
46	detachable housing
47	housing interior space
48	leaf valve
49	rubber damping element

50	rolling piston, piston
51	upper segment
52	bore
53	recess
55	lower segment
56,57	exterior walls
58,59	clamping rings
61	blind-hole bore
62	interior hollow space, central
63	bores
64	leaf valve
65	exterior hollow space, annular space
66	tubular membrane
67	ring adapter
68	valve
69	adapter, adapter having articulated joint
70	hydraulic accumulator
71	membrane
72	gas cushion
74	housing
75	fluid space
76	working line, tubular connector
77	choker valves, pressure stage valves
80	shock absorber
81	shock absorber rod
82	tubular connector, pump connection
86	cover, sleeve cylinder
88	extension of shock absorber tube
90	spring ring
92,94,96	O-ring
	D1 interior diameter outer bell
	Da exterior diameter first piston
	Db exterior diameter second piston